PRINCIPLES
OF
PHYSICS,
OR
NATURAL PHILOSOPHY;

DESIGNED FOR THE

Use of Colleges and Schools.

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§ 5. Action of different Bodies upon Heat.

I. SURFACE ACTION.

635. **Reflection of heat.—Conjugate mirrors.**—Radiant heat, like light, is reflected at the same angle at which it falls upon any reflecting surface. This law in respect to light has been fully illustrated in the chapter on that subject.

If a piece of bright tin-plate is held in such a position as to reflect the light of a clear fire into the face, the sensation of heat will be felt the moment the light is seen.

Conjugate mirrors.—The reflection of heat may be shown in a still more striking manner by the apparatus called the conjugate mirrors, fig. 477, consisting of two similar parabolic mirrors, arranged exactly opposite to each other, at a distance of ten or twelve feet. In the focus of one mirror is placed a heated body, as a mass of red-hot iron, and in the other a portion of an inflammable substance, as gunpowder or phosphorus. Certain of the heat-rays pass directly from A to B; the greater part, however, reach B, by being twice reflected. The rays emitted from A are reflected by the mirror, M, in a direction parallel to its own axis; these rays are received by the second mirror, M, and, by reflection, are conveyed to the focus B, igniting the gunpowder or phosphorus placed at that point.

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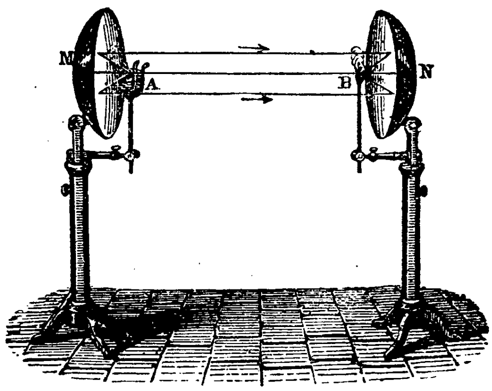

The reflection of heat in vacuo, takes place according to the same laws as in air.

636. **Determination of reflective power.**—Different bodies possess very different powers of reflection. This is well illustrated by the apparatus, fig. 478, designed by Leslie.

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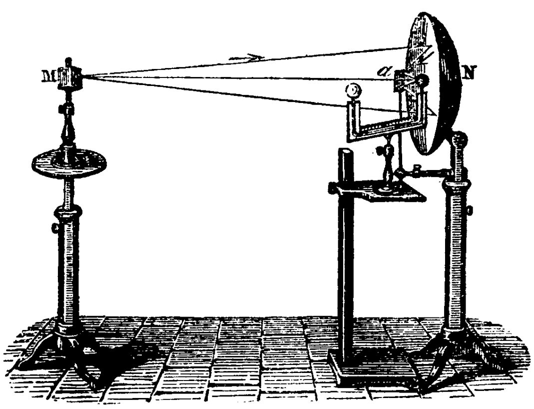

The source of heat is a cubical tin canister, M, filled with boiling water. A plate, *a*, of the substance whose reflective power is to be determined, is placed between the mirror and its focus. The rays of heat emitted from M, which are directed upon the mirror N, are reflected upon the plate *a*, and from this, upon the bulb of the thermoscope, placed at the point where the rays are brought to a focus. The temperature indicated by the thermoscope is found to vary with the nature of the plates.

The causes which modify the reflective power of bodies will be given hereafter.

637. **Absorptive power.**—Different bodies possess very different powers of absorbing the heat thrown upon them. The absorptive power of a body is always in the inverse ratio of its reflective power; that is, the best reflectors are the worst absorbents, and *vice versa*.

The absorptive power of bodies may be determined by a modification of the apparatus, fig. 478. At the focus of the mirror, N, is placed the bulb of a thermoscope, which is successively covered with different substances, as with lampblack, Indian ink, gum lac, metallic leaf, &c. Leslie has been the principal experimenter in this department of heat. A smoke-blackened surface, and a surface covered with carbonate of lead, absorb nearly all the radiant heat thrown upon them; glass, $\frac{90}{100}$; polished cast iron, $\frac{25}{100}$; tin, $\frac{14}{100}$; silver, $\frac{3}{100}$. Table no. VIII., Appendix, gives the results obtained by Messrs. de la Provostaye and Desains.

All black and dull surfaces absorb heat very rapidly when exposed to its action, and part with it again slowly by secondary radiation. The different powers of absorption, possessed by the different colors, may be illustrated by repeating Franklin's experiment. Pieces of the same kind of cloth, of different colors, were placed upon the snow; the black cloth absorbed the most heat, so that after a time it sunk into the melted snow beneath it, while the white cloth produced but little effect; the other colored cloths produced intermediate effects. Ranged according to their absorbent powers, we have, 1. Black (warmest of all); 2. Violet; 3. Indigo; 4. Blue; 5. Green; 6. Red; 7. Yellow; and 8. White (coldest of all).

638. **Emissive or radiating power.**—The earliest, and some of the most valuable, observations upon this subject, were published by Sir John Leslie, in his Essay on Heat, in 1804. Leslie proved that the rate of cooling of a hot body is more influenced by the state of its *surface*, than the nature of its *substance*. It also varies greatly with different substances, as may be seen in the table below.

Leslie employed in his experiments the apparatus, fig. 478. A bulb of a thermoscope was placed in the focus of the mirror, the other bulb being protected from the radiant heat by a screen. The cubical vessel containing boiling water, has its lateral faces covered with different substances, which are successively turned toward the mirror.

The table below gives the results as obtained by Leslie. Lampblack, possessing the greatest emissive power, is called 100.

Lampblack . . .	100	Indian ink . . .	88	Polished lead . . .	19
Water (by calc'n) .	100	Ice	85	Mercury	20
Writing paper . .	98	Minium	80	Polished iron . . .	15
Sealing wax . .	95	Plumbago	75	" silver, tin,	
Crown glass . . .	90	Tarnished lead . .	45	" copper, gold,	12

Messrs. De la Provostaye and Desains, and also Melloni, have obtained results differing somewhat from those of Leslie. See Table VI., Appendix. Melloni found that the radiant and absorbent powers of surfaces were not always proportional, as the following table shows:—

	Lampblack.	Carbonate of Lead.	China Ink.	Isinglass.	Lac.	Metallic Surface.
Absorptive power .	100	53	96	52	52	14
Radiant power .	100	100	85	91	72	12

Melloni has also found that the absorbent power of surfaces varied considerably, according to the source of the radiation, and the temperature of the radiant body. (See Table IX.)

From Melloni's experiments may be drawn the following conclusions :—

1. That bodies agree very nearly, but not exactly, in their emitting and absorbent powers.

2. That their absorbent power varies very remarkably with the origin and intensity of the calorific rays.

3. That they approach each other more and more in their power of emitting and absorbing rays of heat, when the temperature approaches that of boiling water; and that, when at exactly that temperature, the emitting and absorbent powers coincide.

639. **Causes which modify the emissive, absorbent, and reflective powers of bodies.**—Not only do different bodies possess the powers of reflection, absorption, and emission in different degrees, but the physical condition of the material affects them in an important manner. So also the obliquity of the incident rays, the source of heat, and the thickness of the superficial layer, exercise great influence.

The absorbent and emissive powers of metallic plates are diminished if they are hammered or polished. The opposite effect is produced if the plates are scratched or roughened. This is doubtless owing to the change in density which the superficial layers of the plates undergo by these operations. For the same reason, the reflective power of a substance is generally increased by polishing or hammering, and diminished by roughening or scratching it; which latter also causes a portion of the heat to be irregularly reflected. That this is the true explanation is probable from the fact, that if such materials as ivory or coal are taken, whose density will not be changed by roughening or polishing, the reflective and absorbent powers remain the same.

The thickness of the superficial layer has an influence on the reflective power of bodies. Leslie covered a mirror with successive coatings of varnish; the reflection diminished as the number of layers increased, until their thickness amounted to twenty-five thousandths of a millimetre, when it remained constant. While a vessel covered with layers of varnish or jelly had its emissive power increased with the number of layers, until they reached sixteen (with a thickness of 0·034 m. m.), when it remained constant, even upon the addition of other layers. The absorbent power of substances varies with the nature of the source of heat. Thus a substance covered with white lead, absorbs nearly all the thermal rays from copper, heated to 212° F.; 56 of those from incandescent platinum; and 53 of those from an oil lamp. Lampblack is the only substance which absorbs all the thermal rays, whatever be the source of heat. This subject has been ably treated by Prof. A. D. Bache.*

The absorptive power varies with the inclination of the incident rays; the smaller the angle of incidence the greater is the absorption. This is one of the reasons why the sun heats the earth more in summer and less in winter.

The reflective power of glass increases with the angle of incidence, but with metallic surfaces the proportion of heat reflected diminishes with the angle of incidence, and is the same as the proportion of light reflected, § 407.

640. **Applications of the powers of reflection, absorption,**

* Am. Jour. Sci. [1] XXX. 16, 1836.

and radiation are often made in the economical use of heat. We shall refer only to the more familiar examples.

Meat-roasters and Dutch-ovens are constructed of bright tin, to direct the heat from the fire upon the article cooking.

Hoar frost remains longer in the presence of the morning sun upon light-colored objects than upon the dark soil, because the latter absorbs much of the heat, while the former, reflecting it, remain too cold to thaw the frost. Water is slowly heated in bright metallic vessels, as in a silver cup or a clean bright kettle, because they are poor absorbents, but if the sides and bottom of the vessels become covered with soot, the water is heated quickly.

To keep a liquid warm it should be contained in a vessel composed of a poor radiating material. Hence if tea and coffee pots, &c., are made of polished metal, they retain the heat much longer than those which have a dull surface or are composed of earthenware.

Stoves of polished sheet-iron radiate less heat, but keep hot longer than those made of cast-iron with a rough and dull surface.

Pipes conveying steam should be kept bright or thoroughly covered with felt or cloth until they reach the apartments to be warmed, and there their surfaces should be blackened in order to favor the process of radiation.

II. DIATHERMANCY.

641. **Transmission of radiant heat.**—Light passes through all transparent bodies from whatever source it may come. The rays of heat from the sun also, like the rays of light from the same luminary, pass through transparent substances with little change or loss. Radiant heat, however, from terrestrial sources, whether luminous or not, is in a great measure arrested by many transparent substances as well as by those which are opaque.

The glass of our windows remains cold, while the heat of the sun, passing through it, warms the room. A plate of glass held before the fire stops a large part of the heat, although the light is not sensibly diminished.

Melloni terms those bodies which transmit heat *diathermanous*, or *diathermic* (from the Greek, διά, though, and θερμαίνω, to heat); those bodies which do not allow this transmission of heat are termed *athermanous*, or *adiathermanic* (from *alpha*, privative, and θερμαίνω).

It appears that many substances are eminently diathermanous, which are almost opaque to light; smoky quartz for example.

Prevost of Geneva, and De la Roche, in France, in 1811 and 1812, discovered many of the phenomena of diathermanous bodies, but it is from the beautiful researches of Melloni, in 1832—1848, that our knowledge upon this subject has been chiefly derived. Melloni, called by De la Rive "the Newton of heat," died of cholera at Naples, in August, 1854.

642. **Melloni's apparatus.**—The apparatus used by Melloni in his researches upon the transmission of heat, is represented in all its essential details in fig. 479.